THE

Blowpipe Manual.

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Translator's Preface.

This little manual has been prepared for the use of the students of the Massachusetts Agricultural College.

Those who desire further information upon this most important subject are referred to Plattner's "Art of Assaying with the Blowpipe."

Contents.

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ABBREVIATIONS EMPLOYED IN TABLES II. AND III.

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Bx.—Borax or Biborate of Soda.

Ch.—Charcoal.

Ct.—Coating or Incrustation.

OFl.—Oxidizing Flame.

RFl.—Reducing Flame.

Sd.—Carbonate of Soda.

SPh.—Salt of Phosphorus or microcosmic salt, a phos-
phate of soda, ammonia and water, which when heated
loses its water and ammonia and becomes a monobasic
phosphate of soda.

Alphabetical List of Certain Substances which may be Detected with the Aid of the Blowpipe.

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Introduction.

The blowpipe is a simple instrument which has for several centuries been used by workers of metals in various countries to produce suddenly an intense heat. Its use having been chiefly to melt the solder employed in fastening together pieces of more infusible metals, it is called by the Germans soldering pipe. The simplest and most ancient form of the blowpipe is a hollow, conical, metallic tube, which at the small end is bent without a sharp turn to a right angle. In using, the larger end of this is taken into the mouth and a stream of air blown into it, which is applied as it issues from the point exactly like the blast from a bellows. The blowpipe may, therefore, be regarded as a small bellows fed by the mouth, and its heating effect depends upon the same principles. In this rude application and form the blowpipe was of no importance to science. This it came first to possess when the careful study of several scientific men had converted it into one of the most valuable instruments for the chemist and mineralogist, as well as for miners and metallurgists. The fol-

lowing historical sketch shows how this was gradually accomplished.

Anthony Swab, a Swedish counselor of mines, who lived in the first half of the eighteenth century, was, so far as is known, the first who undertook to apply the blowpipe to the chemical examination of ores and minerals. Next to him, the Swedish mineralogist Cronstedt, used the blowpipe for determining and distinguishing minerals, with special reference to the chemical system of mineralogy published by him in 1758. Engestrœm, who in the year 1765 translated this system into English, added a description of Cronstedt's method of using the blowpipe. In the year 1773 this description was translated into Swedish, and soon after, into several other European languages. Imperfect as the application of the blowpipe then was, it attracted immediately great attention from the rapidity and certainty of its results. Nevertheless, the new art, which easy as it appeared required long continued practice, made at first but little progress. It received important assistance from the efforts of Bergmann, who employed the blowpipe for qualitative examinations in the whole province of inorganic chemistry, and showed how by its aid very minute quantities of mineral substances could be detected, the discovery of which in any other way would be much more difficult. Bergmann published the results of his experiments in a work, which was printed in Latin at Vienna in 1779, and was translated into Swedish by Hjelm in 1781. Upon the death of Bergmann, which happened soon after, (in 1784), Gahn pursued still

further the path struck out by the latter. He attained by persevering zeal to great skill in the use of the blowpipe, without, however, recording anything of his rich experience, which would have been for the most part lost except for his obliging readiness to communicate the art to any one desirous of acquiring it. The young Berzelius, whom Gahn regarded with peculiar interest as a student of science, was thus enabled to possess himself of his knowledge, and upon this foundation to build greater. Gahn had made a good selection; a person better adapted for this further development of the art could scarcely have been found. By him the application of the blowpipe was not only in a high degree perfected and extended, but at the same time by his personal instructions and writings so widely diffused that it has now become an essential part of the knowledge of every chemist and mineralogist. In the year 1821 Berzelius published his excellent "Use of the Blowpipe in Chemistry and Mineralogy," of which since that time several editions have appeared and which has been translated for the use of American students by Professor J. D. Whitney.

All the efforts of those who thus far had used the blowpipe in chemical experimentation had been directed to qualitative analysis. Harkort, however, seizing upon the fruitful idea of employing the blowpipe also in quantitative analysis became the founder of a new branch of the blowpipe art. In 1827 appeared as the result of his experiments made in Freiberg the first number of his "Art of Assaying with the Blowpipe" containing

the article on silver. He was prevented from issuing the second number, which was to contain the methods of determining lead, copper and tin, by a call to Mexico, where he died a few years after. Plattner, his successor, perceiving the importance of developing the subject, employed himself for many years in applying to practice the idea of Harkort. His perseverance and ingenuity enabled him to bring the art of assaying quantitatively with the blowpipe to a degree of perfection which had been previously thought impossible. Plattner has given the results of his experiments both in qualitative and quantitative assaying in his work, "Art of Assaying with the Blowpipe," of which the first edition appeared in 1835 and the second in 1847, and which has been translated and published in London.

The methods of assaying qualitatively and quantitatively with the blowpipe, in the state of perfection to which they have been brought by Berzelius and Plattner, are sciences so extensive that a considerable amount of time and practice are required to become familiar with them. Especially is this true of quantitative assaying, which indeed is seldom acquired by chemists, but is almost exclusively employed by practical metallurgists.

The following description of the apparatus, reagents and methods to be employed in qualitative analysis with the blowpipe, is believed to be sufficient for the use of beginners, and even for most of the students in the scientific schools and colleges of the country.

I.

The blowpipe flame is produced when with the aid
of a blowpipe a current of air is driven in accordance
with certain rules through the flame of a candle or
lamp. The best flame for this purpose is that of an
oil lamp with a wide and rather thick wick. The prin-
cipal requisites to the production of a good flame are
first, the steadiness and sufficient durability of the blast;
and secondly, the proper application and management of
the same. The first will be treated of along with the
description of the blowpipe. In regard to the second
point, the flame may be made to produce upon the
heated substance either an oxidizing or a reducing
effect.

The oxidizing and reducing flames are the principal
agents in the whole art of assaying with the blowpipe.
He who understands how to produce these flames of
the right kind and of sufficient permanence has over-
come one of its most difficult points.

To form a reducing flame, the point or jet of
the blowpipe is held parallel with the somewhat

obliquely cut wick and in such a way that it just touches the side of the flame. The result, will be a yellow, luminous flame.

An oxidizing flame is produced when the blowpipe jet is introduced into the flame about one-third the width of the wick. At the same time it is well to blow a little harder than in the production of the reducing flame. The oxidizing flame is of a blue color and possesses but little illuminating power.

The yellow color and luminous character of the re- ducing flame result from the solid particles of carbon, which unconsumed, but white-hot, float in the burning gases till they are burnt upon the outside of the conical flame. In the oxidizing flame, which exhibits the blue color of burning carbonic oxide gas, these particles of carbon are wanting.

It is not difficult to give the reason for the production of these unlike flames. In the reducing flame the less powerful blast from the blowpipe drives the whole flame before it without causing a complete mixture of the com- bustible gases with the air; while in the oxidizing flame a more powerful stream of air is thrown directly into the flame, and is thus more thoroughly mixed with the burning gases. In the latter case, therefore, a much more complete combustion must take place than in the former.

If a piece of a substance capable of oxidation be held directly before the point of the oxidizing flame, it will be heated by it, and will be oxidized by the surrounding atmospheric air. If a powerful blast be used in this

operation, a portion of the air will pass unconsumed through the point of the flame and increase its oxidizing effect. Not only is the oxidizing flame employed for oxidation, but also, on account of the greater intensity of its heat, for determining the fusibility of substances. It should here be observed that the point is the hottest part of the flame.

The reducing flame has the greatest reducing effect when the substance operated on is introduced so far into the flame as to be completely surrounded by it and thus protected from the oxidizing influences of the atmospheric air. It must not, however, be introduced so far into it as to allow it to become covered with carbon, which would diminish the heat, and sometimes produce other injurious effects.

A.—THE BLOWPIPE.

The most convenient form of the blowpipe is that invented by Berzelius. It consists of five parts, which are so fitted together that they can be readily taken apart for cleansing or transportation. These parts are a mouthpiece, a narrow tube seven to nine inches long, an air-chamber to collect the condensed vapor of the breath, a small tube inserted into the air-chamber at right-angles to the larger one, and a jet with a minute orifice for the escape of the blast.

The mouthpiece may be either funnel-shaped to press against the lips, in which case it is made of horn, or a mere extension of the larger tube, formed of bone, ivory or silver, the tube itself being usually of brass.

The jet should be a conical piece of platinum properly bored and drilled to fit the tip of the shorter tube and to allow the escape of a very small stream of air. Care must be taken that the orifice be not too much enlarged in removing the carbon which may collect upon and obstruct it. This is best done by heating the jet to redness.

With sufficient practice it is possible by using the wide mouthpiece to blow uninterruptedly from five to ten minutes. During this continuous blowing the experimenter must breathe through the nose, using the palate as a valve, and force the air out by means of the muscles of the cheeks.

B.—THE BLOWPIPE FLAME.

The flame for use with the blowpipe may be that of coal gas, a candle, or a lamp filled with oil, burning fluid or alcohol. Where gas cannot be had, it will be found convenient to have both an alcohol and an oil lamp. These may be either of glass or metal.

C.—SUPPORTS AND HOLDERS FOR THE SUBSTANCES TO BE HEATED.

For holding the substances which are to be exposed to the flame of the blowpipe must be employed, of course, materials which are not easily injured by heat. The following articles are most commonly used :—

1. Charcoal.—The best for this purpose is a well burnt, compact and dry coal of pine or other soft wood,

free from knots, and having the rings of growth as close
together as possible. Its good quality may be known by
its clear, ringing sound when ˚struck. This should be
sawed into parallelopipeds six inches in length and two
in width in such a way that the rings of growth are
cut off at right-angles to two of the long sides. These
sides of the coal are the ones for use. The substance to
be heated is laid near the edge of the coal, sometimes in
a shallow depression made in it. The other two long
sides of the coal, which run parallel with the rings of
· growth or rather with tangents to these, are unfit for
use, since in consequence of their heterogeneous struc-
ture they often burn with very uneven surfaces
and sometimes snap off. A substance is heated upon
coal when it is intended to reduce it, to prevent its oxid-
ation, or when the unavoidable reducing effect of contact
with coal can exert no injurious influence upon the de-
sired result.

2. Platinum Wire, about 0.4 of a millimeter in thick-
ness. A long piece of this is bent several times around
in the form of a ring and the free ends bent up in-
to small hooks. The ring is held upon the index
finger of the left hand, and one of the hooks, filled
with the substance to be examined, exposed to the flame
of the blowpipe. Borax, or salt of phosphorus, is com-
monly melted first to a transparent bead upon the hook,
and then the substance to be tested, in the form of small
pieces or as a fine powder, heated with it, in order to
observe its reaction with these fluxes both in the oxi-
dating and in the reducing flame. Of course, care

must be taken not to treat in this way metals or other substances which under such circumstances would attack the platinum wire.

3. Platinum Foil.—This is used for fusing substances which must not be subjected to any reducing influence, as is unavoidable upon coal. The platinum foil, which should be about 2 inches long and 1 inch wide, may be laid upon a piece of charcoal or held in forceps.

4. A Platinum Spoon, about half an inch wide. While in use the handle may be fastened to a holder made for the purpose and furnished with a screw for securing it, or may be stuck into a cork. Such a spoon is used for melting certain substances with bisulphate or nitrate of potassa.

5. Forceps, with platinum points. Their form is such that the two platinum points are separated by pressing upon the heads of rivets. Between the extremities of the platinum points is introduced a fragment of the substance to be tested before the blowpipe either with reference to its fusibility or the color which when heated it imparts to the blue flame. The whole forceps are from 5 to 6 inches long.

6. Glass Tubes, about 6 millimeters in diameter, and from 5 to 6 inches long. These are employed chiefly for roasting substances containing sulphur, arsenic, selenium, tellurium or antimony, which when heated with certain precautions in an open tube either deposit various sublimates upon the inner surface of it or give off an odor by which they may be recognized.

7. Glass Mattrasses, which can be easily made by fusing together one end of a glass tube. Their length should be about 3 inches. They are used in heating substances which contain volatile ingredients to protect them as much as possible from the influence of the air. The volatile substance driven off is deposited, in this case, upon the inner surface of the tube, but not in an oxidized condition as when heated in an open tube.

D.—The Blowpipe Reagents.

In most blowpipe experiments the number of reagents employed is very limited and the quantity of these required very small. There are only three reagents which can be said to be extensively used.

1. Soda.—Anhydrous carbonate of soda, which for certain purposes must be free from sulphuric acid. Soda is used principally to assist in the reduction of metallic oxides and sulphides upon charcoal, to decompose silicates and to determine the solubility or insolubility of a substance when melted with it.

2. Borax.—Purified borax freed by heat from the greater part of its water of crystallization and pulverized. In using it, the red-hot hook of the platinum wire is dipped into the powder and the portion adhering to it melted in the flame of the blowpipe, and this operation is repeated till the bend of the wire is filled with a globule which both hot and cold must appear perfectly transparent and colorless. The still soft bead of borax is then dipped into the powder of the substance to be tested, so that a suitable quantity of the same ad-

heres to it, which can then be subjected to the influence of the melted borax glass in the flame of the blowpipe. The solubility or insolubility of the assay is to be observed, and also the color of the bead in the oxidizing and in the reducing flame both while hot and after cooling.

3. Salt of Phosphorus, the well known double phosphate of soda and ammonia. It cannot be melted to a bead directly upon the platinum wire without difficulty, (since, so long as ammonia and water are disengaged, it drops off easily), and must, therefore, first be freed from these by heating gradually upon charcoal, and then taken upon the wire. The use is exactly like that of borax.

Besides these principal reagents, a few others are, in certain cases, employed, viz: Saltpeter, for oxidizing melted substances. Bisulphate of Potassa, for expelling and determining certain volatile substances, (lithia, boracic acid, nitric acid, hydrochloric acid, bromine, iodine), as well as for the decomposition of titanates, tantalates and tungstates. Nitrate of Cobalt, chemically pure and in solution, especially for testing for alumina, magnesia, oxide of zinc, oxide of tin, and titanic acid, which moistened with the solution of cobalt and heated assume certain characteristic colors. Silica, for various purposes. Fluor-spar, mixed with a certain quantity of bisulphate of potassa, for detecting lithia and boracic acid. Oxide or Oxalate of Nickel, for determining the presence of a large quantity of potassa in salts containing at the same time soda and lithia. Oxide of Copper, for detecting chlorine, bromine and

iodine. Tin, in the shape of foil, for assisting in the reduction of substances dissolved in borax, or salt of phosphorus. The hot bead, resting upon charcoal, is to be touched with tin foil, so that a portion of this remains upon it, and then heated a few seconds in as powerful a reducing flame as possible. Silver, for detecting sulphur and sulphuric acid.

The blowpipe reagents may be best kept in bottles, well stopped with ground glass stoppers,—which may be packed in a wooden box constructed for the purpose. In traveling, means should be adopted to prevent the stoppers from becoming loose and falling out.

E.—OTHER ARTICLES NECESSARY IN ASSAYING WITH THE BLOWPIPE.

The method of using these articles, of which some are rather convenient than indispensable, requires no explanation. The following are, therefore, merely mentioned : a hammer, a small anvil, a steel mortar, an agate mortar, files of various sorts, a knife, scissors, a magnet, a microscope, &c., &c.

II.

QUALITATIVE EXAMINATION WITH THE BLOWPIPE.

This consists of the performance of certain operations, and the accurate observation of the resulting phenomena, from which the presence or absence of certain substances may be known. These operations may be undertaken most advantageously in the following order, viz: Test of the substance to be examined, first, in a glass matrass, i. e. in a glass tube closed at one end; second, in a glass tube open at both ends; third, on charcoal; fourth, in the platinum forceps; fifth, in the borax bead; sixth, in the phosphorus bead; seventh, with soda. After these tests, it is often necessary to make some experiments for the detection of certain substances, the presence or absence of which could not be positively determined by the preceding operations.

1.—TEST IN GLASS MATRASS.

The clean and perfectly dry matrass, containing a small quantity of the substance to be examined, is heated at the lower end at first gently over the flame of a spirit lamp, and then gradually more intensely before the blowpipe, till the glass begins to soften.

It is to be noticed whether anything is sublimed or vol-
atilized, as ex. gr. water, quicksilver, sulphur, selenium,
tellurium, arsenic. The first three may be readily recog-
nized from their well known properties. In case water is
sublimed, it should always be noticed whether it gives an
acid or alkaline reaction with litmus paper. When organic
substances are present, the fluid deposited on the walls
of the tube has a characteristic burnt taste and odor. A
microscope is often necessary to detect a small sublimate
of quicksilver; its use should indeed rarely be dispensed
with in these operations. Selenium gives a red subli-
mate; if a large quantity be present so that a thick crust
is deposited, the color in the lower part of the tube is
steel-gray. Tellurium produces a gray sublimate. Ar-
senic yields a black deposit, which, when the quantity is
considerable, has a somewhat metallic luster. It must
not, however, be concluded, because these reactions do
not appear, that these elements are not present, since
sulphur, selenium, tellurium and arsenic especially
may occur in compounds from which they either can
not be liberated by such ignition, or at least not in a
pure condition. It is also to be observed that two or
more of them may be present in a compound and may
be sublimed together, by which the difficulty of recogniz-
ing them is more or less increased. This is very often
the case with sulphur and arsenic. These sometimes
give a sublimate, which below consists of metallic arsenic,
but higher up appears successively black, brown, red
and yellow; colors due to sulphide of arsenic, which is
more volatile than the metal. Oxygen and ammonia,

when disengaged from a substance by heat, may also be detected in the matrass; the first, by introducing a burning splinter of wood; the last, by the introduction of a strip of reddened litmus paper.   Commonly, however, ammonia is not given off in a pure state but combined with an acid, and then a white sublimate of an ammoniacal salt is deposited.   By mixing the assay with lime or soda, and then heating it in a mattrass, free ammonia is liberated and easily recognized.   Some other substances, especially fluorine, chlorine, bromine, iodine and nitric acid, can be detected in the matrass; since this, however, cannot in most cases be done by heating the substance under examination alone, but only by the use of some particular reagent, the method will be given in the eighth section, which treats of the performance of special experiments for the detection of certain substances.

It is to be observed, secondly, whether the substance heated is in any way altered, ex. gr. changes its color and perhaps in cooling resumes it, varies its form or state of aggregation, exhibits a flash of light or phosphorescence, decrepitates, &c., &c.   To treat in a special manner all such cases here would occupy much space, and still not obviate the necessity of more exact chemical knowledge, which the skillful experimenter with the blowpipe must always have at command.

The test in the matrass gives in many cases, as appears from the preceding, no distinct proof, but often only indications of the presence of substances which can be determined with absolute certainty only after still further

experimentation. The indications are nevertheless of importance, and afford much assistance towards the final decision.

2.—TEST IN THE OPEN TUBE.

A portion of the assay finely pulverized is introduced about a half an inch into the tube, and this gradually heated at the place where the substance lies. The tube should be held a little inclined, so that the current of heated air passes over the assay, and upwards through the upper and longer part. In this way the assay is roasted, i. e. exposed to an oxidizing heat, by which various substances are volatilized and rendered recognizable. Sulphur is disengaged as sulphurous acid, which may be easily known by its peculiar suffocating odor. Selenium is but little oxidized, and deposits a red or steel-gray sublimate, at the same time giving the very characteristic odor of selenium vapor—resembling that of decayed horseradish—a ready and sure proof of its presence. Arsenic is volatilized as arsenious acid, antimony, as oxide of antimony and tellurium as tellurous acid, all of which form a white sublimate. That of arsenious acid is distinctly crystalline, while the others appear pulverulent. Arsenious acid and oxide of antimony can be driven forward by heat from the place where they have been deposited, but in the case of tellurous acid, this takes place only in appearance, since it fuses to small transparent drops, which may be detected sometimes by the naked eye, though better with the aid of a microscope.

The roasting process must be carried on slowly with

a gradually increasing temperature and a good current of air, produced by the inclination of the tube; since otherwise, unoxidized volatile substances might be sublimed, and the assay fused together so as to prevent further oxidation. To roast a substance as completely as possible, it is necessary after heating it some minutes, to grind it in an agate mortar, and then to repeat the roasting. This alternate heating and grinding must be continued till nothing more is sublimed.

3—TEST ON CHARCOAL.

The same things are to be observed in heating on charcoal as in using the matrass. Especially important is it to become familiar with the color and certain other properties of the incrustations which different substances deposit when heated on charcoal. These are more particularly treated of in the following synopsis taken from Plattner's "Art of Assaying with the Blowpipe."

SELENIUM melts easily, and gives in the oxidizing or reducing flame brown fumes, and deposits an incrustation which at a little distance from the assay is steel-gray, with a slight metallic luster, and at a greater distance, dull and dark-gray, inclining to violet. This incrustation is readily driven from one place to another by the oxidizing flame, but, if touched with the reducing flame, vanishes, coloring the flame at the moment beautiful ultramarine. When selenium fused on coal ,or a deposit from it, is touched with the blowpipe flame a strong odor of decayed horseradish is perceptible, due

to the gaseous, colorless oxide of selenium which is thus produced.

TELLURIUM melts very easily, gives off fumes and deposits on the coal, not far from the assay, both in the oxidizing and in the reducing flame, tellurous acid. The deposit is white, with red or dark-yellow edges, and may be driven from place to place by the oxidizing flame, but in the reducing flame vanishes, coloring the flame at the same time green, or, when selenium is present, bluish-green.

ARSENIC volatilizes without fusing, and deposits upon the coal, in the reducing as well as in the oxidizing flame, arsenious acid. The deposit is white, in thin layers, grayish, and at some distance from the place where the assay was laid. It is removed instantly when merely warmed by the blowpipe flame. If heated suddenly in the reducing flame, it vanishes, giving the flame a feeble light-blue color. When volatilized it gives a strong alliaceous odor, which is peculiar to the suboxide of arsenic.

ANTIMONY fuses readily, and incrusts the coal with oxide in both flames. The incrustation is white, in thin layers, bluish, and nearer the assay than that of arsenious acid. By a gentle heat from the oxidizing flame, it may be driven from one place to another without coloring the flame, but, if exposed to the reducing flame it changes its positions with a slight greenish-blue color. The oxide of antimony being much less

volatile than the arsenious acid may be easily distinguished from it.   If metallic antimony be melted on charcoal and heated to redness, and then allowed to remain undisturbed, it continues a long time red-hot, and gives off dense white fumes, which are partly deposited upon the coal, and partly around the globule of metal in white, pearly crystals.   This phenomenon depends on the fact that the red-hot fluid globule of metal absorbs oxygen from the air, oxide of antimony is formed, and thus so much heat liberated as is necessary to keep the very fusible antimony in a melted state for some time, till it becomes covered with crystals of the oxide.

BISMUTH fuses very easily, and deposits on the coal oxide of bismuth, both in the oxidizing and in the reducing flame.   The deposit is, while hot, dark orange-yellow, when cold, lemon-yellow, and in thin layers, bluish-white.   The yellow deposit consists of pure oxide of bismuth, and the bluish-white, which is farthest from the assay, of carbonate of bismuth.   The bismuth incrustation is deposited a little nearer the assay than that of antimony.   It may be driven from place to place by either flame, since the oxide is reduced on the coal at a red heat, and the metallic bismuth then volatilized and reoxidized, but does not, when heated in the reducing flame, impart to it any color.

LEAD melts easily, and gives the coal in either flame an incrustation of oxide at the same distance from the assay as that of bismuth.   The deposit while hot, is dark lemon-yellow, after cooling, sulphur-yellow, and in

thin layers, bluish-white. The yellow crust is pure oxide of lead, and the bluish-white, carbonate of lead. The yellow deposit when heated in the oxidizing flame changes its place for the same reason as the oxide of bismuth, and without coloring the flame; in the reducing flame it changes its position, tinting the flame with ultramarine.

THALLIUM melts, volatilizes and deposits a brown incrustation, coloring either flame a brilliant green.

CADMIUM melts readily, takes fire in the oxidizing flame, burns with a dark-yellow flame and brown fumes, and deposits on the coal near the assay oxide of cadmium. This exhibits its peculiar color best when completely cold; it is reddish-brown, in thin layers, orange-yellow. The deposit of oxide of cadimum may, since the oxide is easily reduced, be volatilized by either flame, but without imparting to it any color. Around the outer edge of the incrustation the coal sometimes exhibits pavonian tints.

INDIUM fuses readily, forms in the oxidizing flame a coating brown while hot, and yellow when cold, and which touched with the reducing flame colors it blue.

ZINC fuses easily, takes fire in the oxidizing flame, burns with a very luminous, greenish-white flame and dense white fumes, and gives the coal an incrustation of oxide. This is rather near the assay; while warm, yellow, and when completely cold, white. Heated in the

oxidizing flame it glows, but is not volatilized because it
cannot be reduced by the heated coal on which it rests.
Even in the reducing flame it is volatilized but slowly.

TIN melts without difficulty, and in the oxidizing flame
becomes covered with oxide, which may be removed by a
puff of air ; in the reducing flame the fused metal pre-
sents a brilliant surface and incrusts the coal with oxide.
The incrustation is while hot, slightly yellow, and some-
what luminous in the oxidizing flame; but, upon cooling,
it becomes white.   It is so near the assay as to touch it
on all sides.   It cannot be volatilized.

MOLYBDENUM, in metallic form, cannot be fused
before the blowpipe, but when heated in the exterior
flame gradually oxidizes, and covers the coal, at a little
distance from the assay, with molybdic acid, which is
deposited in some places, especially nearest the assay, in
transparent, crystalline scales, but elsewhere in a pulveru-
lent form.   The deposit has while hot, a yellowish color,
but on cooling becomes white.   The crystalline scales
are best produced, by heating the assay as far as possible
from the point of the blue flame.   The pulverulent mo-
lybdic acid can be driven about by either flame, but the
place which it leaves appears, after it is completely cold,
dark copper red and has a metallic luster, from oxide
of molybdenum, which is formed by the reducing effect
of the coal on the acid, and which is not volatile.   In
the reducing flame, metallic molybdenum remains un-
changed.

SILVER, held for sometime in a fluid condition by a powerful oxidizing flame, gives a very slight deposit of dark red oxide. In combination with a small quantity of lead, there appears, first, a yellow deposit of oxide of lead, but afterwards, when the silver contains less lead, it colors the coal outside the yellow crust dark red. If the silver contain a little antimony, there appears, first, a white incrustation of oxide of antimony, which, if the blowing be continued, becomes red. An alloy of silver, lead and antimony gives, after the latter metals are mostly volatilized, a copious, carmine red deposit. Such a deposit may also sometimes be obtained by heating alone on charcoal a rich ore of silver.

SULPHIDES, CHLORIDES, BROMIDES, AND IODIDES OF THE METALS.—In assaying with the blowpipe, not only are pure metals found, which being somewhat volatile, may be detected by the incrustation which they give the coal when sublimed, but there are also compounds which deposit a white crust upon the coal, that may be driven off by the oxidating flame, and very often resembles closely a deposit of oxide of antimony. Here belong of the sulphides, those of potassium and sodium, which while forming from the sulphates in the reducing flame on coal, yield a white, and not very volatile incrustation of sulphates, produced by the reoxidation of the volatilized sulphides. This, however, does not occur till the sulphates have sunk into the coal, and given off their oxygen. Sulphides of potassium being more volatile than sulphides of sodium, the former are deposited earlier, and in greater quantity than the latter. This deposit,

when touched by the reducing flame, disappears, impart-
ing to the flame, when consisting of sulphate of potassa,
a bluish violet color, and, when of sulphate of soda, a
reddish yellow. Sulphide of lithium, formed by the
reduction of sulphate of lithia on coal, is also volatilized
by an intense heat, but more difficultly than sulphide of
sodium, and gives, instead of a pure white, a greenish
white, thin crust, which touched with the reducing flame
vanishes, coloring the flame carmine red. The sulphides
of lead and bismuth also belong here. Each of these
sulphides, both in the oxidizing and the reducing flame,
affords two different deposits of which the most volatile
is white, and is a sulphate. When these deposits are
heated in the reducing flame, that of lead disappears,
communicating a blue tinge to the flame ; that of
bismuth vanishes, but does not color the flame. The
incrustation nearest the assay consists of the oxide of the
metal, and may be recognized from its color, both while
hot and after cooling. There are indeed several other
sulphides of metals which incrust the coal, when thor-
oughly heated before the blowpipe, with a more or less
abundant white deposit, ex. gr. sulphide of antimony,
sulphide of zinc and sulphide of tin ; but the deposit
consists only of the oxides, and is in the oxydating flame
either volatile or fixed.

Among the chlorides of the metals, several possess the
property, when heated before the blowpipe on coal, of
volatilizing and depositing a white incrustation, viz :
the chlorides of potassium, sodium and lithium, after
sinking into the coal in a fluid state, volatilize and give

a white deposit near the assay, (chloride of potassium yields the most abundant, and chloride of lithium the least, which also instead of being pure white, is grayish); chlorides of ammonium, quicksilver and antimony, which volatilize without melting; chlorides of zinc, cadmium, lead, bismuth and tin, which first melt and then afford two incrustations, viz: a white, volatile one of chloride, and a less volatile one of oxide. These in the reducing flame disappear, a part of them with a colored flame. That of chloride of potassium is bluish, inclining to violet, and that of chloride of sodium, reddish-yellow, of chloride of lithium, carmine red, and that of chloride of lead, blue; the remainder do not color the flame. Chloride of copper fuses and colors the flame intense ultramarine. If the blowing be long continued, it may be observed that one part of the assay is volatilized with white fumes having a strong odor of chlorine, and another deposits on the coal three rings of different colors, of which the one nearest the assay is dark-gray, the next dark-yellow to brown, and the third bluish-white. In the reducing flame a portion of these may be made to change position, coloring the flame at the same time ultramarine.

Of the bromides and iodides of metals which appear on coal very similar to the chlorides, should be particularly noticed here the bromides and iodides of potassium and sodium. These melt and are absorbed by the coal, and are then volatilized with white fumes, a part of which forms at some distance from the assay a white crust on the charcoal. This when touched with the re-

ducing flame disappears, the bromide and iodide of po-
tassium coloring the flame bluish, inclining to violet, and
bromide and iodide of sodium, reddish-yellow.

4.—TEST IN THE PLATINUM FORCEPS.

It having been settled by previous experiments that
the assay does not when heated attack platinum, a small
fragment or splinter is taken in the forceps and exposed
to the point of the exterior flame.   Substances which
attack platinum may be heated on coal, or, if easily fusi-
ble, on the platinum wire.   The object is not only to
determine the fusibility of the assay, but also the pres-
ence of certain substances which under these circum-
stances impart more or less distinctly a color to the blue
flame of the blowpipe.   Some substances impart a yel-
low, others a violet, carmine red, green, or blue color.
Plattner, in his work previously quoted, gives on this
subject the following particulars :

YELLOW.—Soda and its salts, when fused on the plat-
inum wire in the point of the blue flame, possess the
property of increasing the size of the exterior flame,
and coloring it intense reddish-yellow.   This reaction is
not prevented by the presence of a large quantity of
other salts, whose bases also color the exterior flame,
though not so intensely as soda.   For the appearance on
coal, see page 32.   If a small splinter of a silicate con-
taining soda be ignited or fused in the point of the blue
flame, it increases more or less the outer flame, according
as it is more or less fusible and contains more or less

soda, tinging it at the same time reddish-yellow. If
the blowing be long continued, this color remains un-
changed, or becomes more intense.

VIOLET.—Potassa, Cæsia and Rubidia, and most of
their salts, except the borate and phosphate, when
fused in the point of the blue flame, color the exterior
flame distinctly violet. If, however, the salt be mixed
with only a very minute quantity of a salt of soda, the
reaction is so changed that while near the assay a slight
violet tinge may be perceived, further from it appears
the intense reddish-yellow of the soda. If the mixture
contain several per cent. of a salt of soda, the reac-
tion of potassa is wholly suppressed, and only that of
soda can be perceived. The reaction of potassa is also
prevented by the presence of a small quantity of a salt
of lithia. For the appearance of some salts of lithia on
coal, see page 32.

Many minerals containing lithia and fusible in the
point of the blue flame communicate a red color to the
exterior flame. This is especially true of the micas from
Altenberg and Zinnwald, which color the outer flame
very strongly; this color diminishes, however, in inten-
sity, as soon as the thin strip is melted to such an extent
that it can no longer be kept perfectly fluid in the flame
of the blowpipe. There are also minerals which give
along with the red of lithia still another color, and in
such a manner that both appear either separate or
mixed. If, for instance, a minute quantity of pulverized
triphyline, (phosphate of lithia, iron and maganese), be

fused on the platinum wire in the blue flame, there appears in the outer flame a carmine-red streak from lithia, surrounded by a green flame resulting from the phosphoric acid. In the forceps this is difficult to observe because the triphyline is too easily fused. If a small piece of amblygonite from Cursdorf, which consists chiefly of phosphates of lithia and alumina, be fused in the forceps in the point of the blue flame, there appears in the exterior flame a yellowish-red streak, which is surrounded by a reddish-yellow flame resulting from the presence of soda. This color continues as long as a portion of the assay is kept in a fluid state.

Silicates containing lithia, which alone impart no red tinge to the exterior flame, do so, according to Turner, when melted with fluor-spar and bisulphate of potassa on the platinum wire in the point of the blue flame, as will be explained in section 8.

STRONTIA.—Chloride of strontium fused on the platinum wire in the point of the blue flame produces instantly an intense red color in the outer flame.

Many other salts of strontia, ex. gr. carbonate of strontia, (strontianite), and sulphate of strontia, (coelestine), when exposed to the point of the blue flame in the forceps color the outer flame at first slightly yellowish, but afterwards carmine-red. The presence of baryta prevents the reaction of strontia.

LIME.—Chloride of calcium tinges the exterior flame red, though not so intensely as chloride of strontium. Most pure calcites as well as massive carbonates of lime

produce at first a feeble yellowish color in the exterior flame, but afterwards when the carbonic acid is driven off, a red, which is, however, less intense than that from strontia. The presence of baryta prevents the reaction of lime. Fluor spar, while fusing, colors the outer flame as deep red as calc-spar. Gypsum and anhydrite produce at first only a feeble yellowish tinge, but afterwards a rather intense red. Phosphate and borate of lime do not give a red, but a green color.

Of the silicates, none afford the reaction of lime except table-spar, which imparts to the exterior flame a slight reddish tinge.

GREEN.—There are seven substances which color the exterior flame green, viz: baryta, molybdic acid, oxide of copper, tellurous acid, phosphoric acid, boracic acid and thallium.

BARYTA.—Chloride of barium when fused on the platinum wire produces in the exterior flame a green color which at first appears only light-green, but afterwards becomes an intense yellowish-green. The color is most beautiful when only a very small quantity of the salt is used. Carbonate of baryta, (witherite), and sulphate of baryta, (heavy spar), when held in the forceps and strongly heated in the point of the blue flame also tinge the exterior flame yellowish-green, though not so deeply as chloride of barium. The presence of lime does not prevent the reaction of baryta. For instance, baryto-calcite, consisting of carbonates of lime and baryta, causes in the exterior a greenish-yellow color;

3

if, however, the blowing be long continued, it may be perceived that the point of the flame is also sometimes of a reddish tinge.

MOLYBDIC ACID.—Molybdic acid, or oxide of molybdenum, when attached to the moistened platinum wire and ignited in the blue flame, colors the exterior flame bluish-green, exactly like baryta, molybdic acid at the same time volatilizing. If a thin scale of natural sulphide of molybdenum be held by the platinum forceps in the point of the blue flame, it does not fuse, but immediately imparts to the outer flame a yellowish-green tinge, resulting from the molybdic acid formed by its oxidization.

OXIDE OF COPPER.—Oxide of copper, alone as well as in combination with certain acids which do not themselves give a colored flame, for instance, with carbonic, acetic, nitric and sulphuric acids, communicates to the exterior flame an emerald-green color. Metallic copper, when heated on coal in the flame of the blowpipe, is easily oxidized, and then tinges the outer flame emerald-green. The iodide of copper causes also a very intense emerald-green color in the exterior flame. Ores of lead containing copper color the outer flame in the center blue from the lead, (see below), and upon the outside, especially near the point, emerald-green. Silicates containing copper, when heated in the forceps with the point of the blue flame, sometimes impart to the exterior flame a very intense emerald-green color, ex. gr. dioptase, and chrysocolla.

This color is also produced by those in which the oxide of copper constitutes an unessential, and only the coloring part of the mineral, ex. gr. turquoise.

TELLUROUS ACID.—Tellurous acid, suspended on the moistened platinum wire, and heated in the point of the blue flame, melts, gives off fumes and colors the exterior flame green. If the tellurous acid, deposited on coal from heating an ore of tellurium, be touched with the point of the blue flame, it vanishes with a green, or when selenium is present, with a bluish green flame.

PHOSPHORIC ACID.—According to Fuchs and Erdmann, phosphoric acid, phosphates and minerals containing phosphoric acid, sometimes alone, and sometimes after being pulverized and moistened with sulphuric acid, impart to the exterior flame a bluish green color. This reaction is so reliable that with suitable care very minute quantities of phosphoric acid may be detected in minerals, when a little of the paste, formed by moistening the powder of the mineral with sulphuric acid, is taken on the platinum wire and exposed to the point of the blue flame. The same is true also of compounds, which from containing a large admixture of soda or other intensely coloring substance, do not alone give the reaction of phosphoric acid. If the salt contain water, it must first be driven off by heating on coal before the blowpipe, and then the anhydrous substance pulverized, moistened with sulphuric acid, and exposed to the blue flame on the platinum wire. If soda be present, the outer flame is tinged very distinctly bluish green at the

moment the phosphoric acid is liberated by the action of
the sulphuric acid, but afterwards assumes the intense
reddish yellow of the soda.   As the bluish green lasts
in some cases but a short time, it must be observed
whether the outer flame is colored bluish green or not, at
the instant the assay is touched with the point of the
blue flame.   Phosphate of lead as well as pyromorphite,
heated alone, tinges the edges of the blue flame of oxide
of lead with a permanent green.

BORACIC ACID.—Both natural and artificial boracic
acid, when melted on the platinum wire in the point
of the blue flame, impart to it a deep yellowish green,
(siskin-green.) If, however, the acid be not perfectly free
from soda, there results in the outer flame a green color,
which is more or less mixed with yellow.   Borax alone
produces no green, but only the yellow of soda.   Anhy-
drous borax, however, when pulverized and moistened
with sulphuric acid, and exposed to the point of the blue
flame, gives for a short time an intense green, which
changes to yellow as soon as the salt is decomposed and
the free sulphuric acid expelled.   Minerals containing
boracic acid, when heated on the platinum wire with
the point of the blue flame, after being pulverized and
moistened with sulphuric acid, almost all communi-
cate to the exterior flame a green color.   Another and
very reliable method of detecting boracic acid in miner-
als from the siskin green color of the outer flame has
been proposed by Turner, and will be found in section 8.

THALLIUM.—Substances containing thallium, when

strongly heated, color the flame bright green, which is changed to yellow and thus obscured by the presence of much soda.

BLUE.—There are some substances which when ignited or fused in the inner flame, color the exterior flame blue, viz: arsenic, antimony, lead, indium, selenium and compounds of copper with chlorine and iodine.

ARSENIC.—Metallic arsenic and the arsenides of those metals which do not communicate any color to the exterior flame, as ex. gr. copper-nickel, cobaltine, &c., &c., when heated by the blue flame on coal, are surrounded by a blaze of a light blue color. If the incrustation of arsenious acid deposited on the charcoal be touched suddenly by the blue flame, it being very volatile may be distinctly observed to disappear with the same light blue blaze. When arseniates whose bases impart no color to the exterior flame, as ex. gr. nickel bloom, cobalt bloom, iron sinter, &c., are exposed in the forceps to the blue flame, they communicate an intense light blue to the outer flame. In many cases a blue color appears even when the base possesses the property of coloring the flame, as ex. gr. arseniate of lime, (pharmacolite.)

ANTIMONY. When metallic antimony is fused within the blue flame on charcoal, the fluid globule of metal is surrounded by a scarcely perceptible blue blaze; but, if the resulting white crust of oxide of antimony be touched with the blue flame of the blowpipe, it disappears tinging the flame greenish blue.

LEAD.—When metallic lead is melted on coal within the blue flame, the fluid metal is surrounded by a blaze of an ultramarine color, and the coal is incrusted with oxide of lead. The oxide of lead may be driven by the blue flame from one place to another, tinging the flame at the same time with blue. Salts of lead, whose acids do not themselves impart a deep color to the exterior flame, communicate to this an intense ultramarine, when fused with the point of the blue flame, either on the platinum wire or in the forceps.

INDIUM.—Compounds of indium color the flame blue.

SELENIUM.—If selenium be melted on coal in the blue flame, it volatilizes, coloring the flame intense ultramarine. A deposit of selenium on charcoal presents the same appearance in the reducing flame.

CHLORIDE OF COPPER.—Natural or artificial chloride of copper, ignited on the platinum wire in the blue flame, tinges the external flame at first intense ultramarine, but afterwards green from the oxide of copper formed.

BROMIDE OF COPPER.—Bromide of copper, treated in the same way as the chloride, colors the flame at first greenish blue, but afterwards imparts the green of oxide of copper.

5.—TEST IN THE BORAX BEAD.

Since this test serves especially to detect the oxides of metals, it is of the first importance that, if the substance to be examined contain unoxidized metals, it should be roasted to oxidize them. Metals combined with sulphur, arsenic, &c., are not only difficultly soluble in borax, but

present appearances differing more or less from those of the oxides. The roasting of the pulverized substance may be performed on coal or in a glass tube. It must be repeated several times to produce the most complete oxidation and volatilize perfectly sulphur, arsenic, etc. Before every new roasting the substance must be ground in an agate mortar. Sulphides and arsenides of metals may be advantageously subjected to alternate oxidating and reducing roastings. The latter are effected by mixing the pulverized assay with coal or plumbago powder, and then heating it in a glass tube or on charcoal. The same directions apply to the next test.

6.—TEST IN THE PHOSPHORUS BEAD.

In this case, as in the preceding, it is important to observe accurately the colors which the beads present while hot, while cooling, and when cold, both in the oxidizing and reducing flames. Beads, in which certain substances are dissolved, possess the property of becoming cloudy or opaque, when treated with an intermittent flame. This process is called flaming. The same result may also generally be produced by a slow and gentle heating of the previously cooled bead. The cloudiness of the bead is also often caused merely by the addition of a larger quantity of the assay.

TABLE I.

1.—OXIDIZING FLAME. A.—BORAX.

COLORS OF THE BEADS.	SUBSTANCES WHICH EXHIBIT THESE COLORS.	
	In the Hot Bead.	*In the Cold Bead.*
Colorless.	Silica, Alumina, Oxide of Tin, Tellurous Acid, Baryta, Strontia, Lime, Magnesia, Glucina, Yttria, Zirconia, Thoria, Oxide of Lanthanum, Oxide of Silver, Columbic Acid, Niobic Acid,	Silica, Alumina, Oxide of Tin,
		Tellurous Acid, Baryta, Strontia, Lime, Magnesia, Glucina, Yttria, Zirconia, Thoria, Oxide of Lanthanum, Oxide of Silver, Columbic Acid, Niobic Acid,
	Titanic Acid, Tungstic Acid, Molybdic Acid, Oxide of Zinc, Oxide of Cadmium, Oxide of Indium, Oxide of Lead, Oxide of Thallium, Oxide of Bismuth, Oxide of Antimony.	Titanic Acid, Tungstic Acid, Molybdic Acid, Oxide of Zinc, Oxide of Cadmium, Oxide of Indium, Oxide of Lead, Oxide of Thallium, Oxide of Bismuth, Oxide of Antimony,
Yellow, reddish yellow to red and reddish brown.	Titanic Acid, (yellow), Tungstic Acid. (yellow), Molybdic Acid, (dark-yellow),) Oxide of Zinc, (slightly yellowish), Oxide of Cadmium, (slightly yellowish), Oxide of Lead, (yellow), Oxide of Bismuth, (reddish yellow), Oxide of Antimony, (yellowish).	

{ Even when added in large quantity. }

{ Only in small quantity; in larger, yellow. }

{ In large quantity; otherwise colorless. }

{ Rendered white and opaque by flaming. }

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TABLE I.—CONTINUED.

1.—OXIDIZING FLAME. A.—BORAX.

COLORS OF THE BEADS.	SUBSTANCES WHICH EXHIBIT THESE COLORS.	
	In the Hot Bead.	*In the Cold Bead.*
Red, yellow, or purple.	Oxide of Cerium, (red), Oxide of Iron, (dark red), Oxide of Uranium, (red), Vanadic Acid. (yellow), Oxide of Chromium, (dark-red),	Oxide of Cerium, (by flaming, enamel-white). Oxide of Iron, (yellow). Oxide of Uranium, (by flaming, enamel-yellow). Vanadic Acid. (yellow). Oxide of Nickel, (reddish brown), Oxide of Manganese, (red, inclined to violet).
Color of Amethyst.	Oxide of Nickel, Oxide of Manganese, Oxide of Didymium.	Oxide of Didymium.
Blue.	Oxide of Cobalt.	Oxide of Cobalt, Oxide of Copper, (blue to greenish-blue).
Green.	Oxide of Copper.	Oxide of Chromium, (inclined to yellow).

TABLE I.—CONTINUED.

2.—Reducing Flame. A.—Borax.

Colors of the Beads.	Substances which exhibit these Colors.	
	In the Hot Bead.	*In the Cold Bead.*
Colorless.	Silica, Alumina, Oxide of Tin, Baryta, Strontia, Lime, Magnesia, Glucina, Yttria, Zirconia, Thoria, Oxide of Lanthanum, Oxide of Cerium, Columbic Acid, Oxide of Didymium, Oxide of Manganese. Niobic Acid, *in small quantity.*	Silica, Alumina, Oxide of Tin. Baryta, Strontia, Lime, Magnesia, Glucina, Yttria, Zirconia, Thoria, Oxide of Lanthanum, Oxide of Cerium, Columbic Acid. *} By flaming, white and opaque. }* Oxide of Didymium, Oxide of Manganese. Niobic Acid, *in small quantity.*
	Oxide of Silver, Oxide of Zinc, Oxide of Cadmium, Oxide of Indium, Oxide of Lead, Oxide of Thallium, Oxide of Bismuth, Oxide of Antimony, Oxide of Nickel, Tellurous Acid, *By long continued blowing; otherwise gray.*	Oxide of Silver, Oxide of Zinc, Oxide of Cadmium, Oxide of Indium, Oxide of Lead, Oxide of Thallium, Oxide of Bismuth, Oxide of Antimony, Oxide of Nickel, Tellurous Acid. *By short continued blowing; otherwise gray.*
Yellow to brown.	Titanic Acid, Tungstic Acid, Molybdic Acid, Vanadic Acid.	Titanic Acid, Tungstic Acid, Molybdic Acid.
Blue.	Oxide of Cobalt.	Oxide of Cobalt, Titanic Acid, *{ By flaming, enamel-blue.*

TABLE I.—CONTINUED.

2.—REDUCING FLAME. A.—BORAX.

COLORS OF THE BEADS.	SUBSTANCES WHICH EXHIBIT THESE COLORS.	
	In the Hot Bead.	*In the Cold Bead.*
Green.	Oxide of Iron, Oxide of Uranium, Oxide of Chromium,	Oxide of Iron, (bottle-green). Oxide of Uranium, " Oxide of Chromium, (emerald-green). Vanadic Acid, (emerald-green).
Gray and cloudy. (*The cloudiness often appears first distinctly during the cooling.*	Oxide of Silver, Oxide of Zinc, Oxide of Cadmium, Oxide of Lead, Oxide of Bismuth, Oxide of Antimony, Oxide of Nickel, Tellurous Acid. *}By short-continued blowing; otherwise colorless}*	Oxide of Silver, Oxide of Zinc, Oxide of Cadmium, Oxide of Lead, Oxide of Bismuth, Oxide of Antimony, Oxide of Nickel, Tellurous Acid. *}By short-continued blowing; otherwise colorless}*
	Niobic Acid, *{By long continued blowing and in large quantity.*	Niobic Acid, *{By long continued blowing and in large quantity.*
Red to brownish-red and cloudy.	Oxide of Copper.	Oxide of Copper.

TABLE I.—CONTINUED.

1.—OXIDIZING FLAME. B.—SALT OF PHOSPHORUS.

COLORS OF THE BEADS.	SUBSTANCES WHICH EXHIBIT THESE COLORS.	
	In the Hot Bead.	*In the Cold Bead.*
Colorless.	Silica, (*very little soluble.*) Alumina, Oxide of Tin, Tellurous Acid, Baryta. Strontia, Lime, Magnesia, Glucina, Yttria, Zirconia, Thoria, Oxide of Lanthanum, Niobic Acid. *{ Even in large quantity. }*	Silica, (*very little soluble.*) Alumina. Oxide of Tin, Tellurous Acid, ⸱ Baryta, Strontia, Lime, Magnesia, Glucina, Yttria, Zirconia, Thoria, Oxide of Lanthanum, Oxide of Cerium. *{ By flaming white and opaque }*
	Columbic Acid, Titanic Acid. Tungstic Acid, Oxide of Zinc, Oxide of Cadmium, Oxide of Indium, Oxide of Lead, Oxide of Thallium, Oxide of Bismuth, Oxide of Antimony. *{ Only in small quantity; in larger, yellowish or yellow. }*	Niobic Acid, Columbic Acid, Titanic Acid, Tungstic Acid, Oxide of Zinc, Oxide of Cadmium, Oxide of Indium, Oxide of Lead, Oxide of Thallium, Oxide of Bismuth, Oxide of Antimony.
Yellow, red- dish yellow to red and reddish brown.	Columbic Acid, Titanic Acid, Tungstic Acid, Oxide of Zinc, Oxide of Cadmium, Oxide of Lead, Oxide of Bismuth, Oxide of Antimony. *{ In large quanti- ty. }*	Oxide of Silver, Oxide of Iron, Oxide of Nickel, Oxide of Uranium, (*yellowsh green*).
	Oxide of Silver, Oxide of Cerium, Oxide of Iron, Oxide of Nickel, Oxide of Uranium. Vanadic Acid, Oxide of Chromium.	Vanadic Acid,

TABLE I.—CONTINUED.

1.—Oxidizing Flame. B.—Salt of Phosphorus.

COLORS OF THE BEADS.	SUBSTANCES WHICH EXHIBIT THESE COLORS.	
	In the Hot Bead.	*In the Cold Bead.*
Color of Amethyst.	Oxide of Manganese, Oxide of Didymium.	Oxide of Manganese, Oxide of Didymium.
Blue.	Oxide of Cobalt.	Oxide of Cobalt, Oxide of Copper, *(to greenish blue.)*
Green.	Oxide of Copper, Molybdic Acid, *(yellowish green.)*	Molybdic Acid, *(slight yellowish green).* Oxide of Uranium, *(yellowish green).* Oxide of Chromium, *(emerald green).*

TABLE I.—CONTINUED.

2.—REDUCING FLAME. B.—SALT OF PHOSPHORUS.

COLORS OF THE BEADS.	SUBSTANCES WHICH EXHIBIT THESE COLORS.	
	In the Hot Bead.	In the Cold Bead.
Colorless.	Silica, (very little soluble). Alumina Oxide of Tin, Baryta, Strontia, Lime, Magnesia, Glucina, Yttria. Zirconia, Thoria, Oxide of Lanthanum, Oxide of Cerium, Columbic Acid, Oxide of Didymium, Oxide of Manganese.	Silica, (very little soluble). Alumina. Oxide of Tin. Baryta, Strontia, Lime, Magnesia, Glucina, Yttria, Zirconia, Thoria. *(By flaming white and opaque.)* Oxide of Lanthanum, Oxide of Cerium, Oxide of Didymium, Oxide of Manganese, Columbic Acid.
	Oxide of Silver, Oxide of Zinc, Oxide of Cadmium, Oxide of Indium, Oxide of Lead, Oxide of Thallium, Oxide of Bismuth, Oxide of Antimony, Oxide of Nickel. Tellurous Acid. *(By long continued blowing; otherwise gray.)*	Oxide of Silver, Oxide of Zinc, Oxide of Cadmium, Oxide of Indium, Oxide of Lead, Oxide of Thallium, Oxide of Bismuth, Oxide of Antimony, Oxide of Nickel, Tellurous Acid. *(By long continued blowing; otherwise gray.)*
Yellow to b'ood-red and brown.	Oxide of Iron, (red), Titanic Acid, (yellow), Titanic Acid, ⎫ containing Niobic Acid, ⎬ Iron, (blood-Tungstic Acid. ⎭ red). Vanadic Acid, (brownish). Oxide of Chromium, (reddish),	Oxide of Iron, Titanic Acid, (containing Iron). Niobic Acid. " " Tungstic Acid, " "

TABLE I.—CONTINUED.

2.—REDUCING FLAME. B.—SALT OF PHOSPHORUS.

COLORS OF THE BEADS.	SUBSTANCES WHICH EXHIBIT THESE COLORS.	
	In the Hot Bead.	*In the Cold Bead.*
Violet.	Niobic Acid (*in large quantity*).	Niobic Acid, (*in large quantity.*) Titanic Acid.
Blue.	Oxide of Cobalt, Tungstic Acid Niobic Acid, (*in very large quantity*)	Oxide of Cobalt, Tungstic Acid, Niobic Acid, (*in very large quantity.*)
Green.	Oxide of Uranium, Molybdic Acid.	Oxide of Uranium, Molybdic Acid. Vanadic Acid. Oxide of Chromium,
Gray and cloudy. (*The cloudiness often appears first distinct'y while the bead is cooling*).	Oxide of Silver, Oxide of Zinc, Oxide of Cadmium, Oxide of Lead, Oxide of Bismuth, Oxide of Antimony, Oxide of Nickel, Tellurous Acid.	
Red to reddish and cloudy.	Oxide of Copper.	Oxide of Copper.

TABLE II.—BEHAVIOR OF THE METAL-

Metallic Oxides in Alphabetic Order.	On Charcoal alone.	With Carbonate of Soda
1. ANTIMONI-OUS ACID.	OFl: It is displaced without change, and deposited upon another part of the Ch. RFl: It is reduced and volatilized. A Ct of antimonious acid is deposited on the Ch, and a greenish blue color imparted to the flame.	On Ch very readily reduced in OFl and RFl. The metal fumes and coats the Ch with antimonious acid.
2. ARSENIOUS ACID.	Volatile below red heat.	On Ch reduced, with emission of arsenical fumes, which are characterized by a strong garlic odor.
3. TEROXIDE OF BISMUTH.	OFl: On platinum foil it fuses readily to a dark-brown mass, which on cooling becomes pale yellow. On Ch in OFl and RFl reduced to metallic bismuth, which, with long blowing, vaporizes, coating the Ch with yellow oxide. The Ct, when touched with the RFl, disappears without coloring the flame.	Easily reduced to metallic bismuth.
4. OXIDE OF CADMIUM.	OFl: On platinum foil unchanged. RFl: On Ch it disappears in a short time and deposits all over the Ch a dark yellow or reddish brown powder; the color can only be clearly discerned after cooling.	OFl: Insoluble. RFl: On Ch readily reduced; the metal vaporizes and deposits a dark yellow or reddish brown Ct on the Ch.

LIC OXIDES BEFORE THE BLOWPIPE.

With Bx on Platinum Wire.	With S Ph on Platinum Wire.
OFL: Dissolves in large quantities to a limpid glass. which while hot appears yellowish, but after cooling colorless. RFl: The glass when treated only for a short time in the OFl becomes on Ch grayish and cloudy from particles of reduced antimony. With tin it becomes gray or black.	OFl: Dissolves with effervescence to a limpid glass, which while hot is slightly yellowish. RFl: On Ch the saturated bead becomes at first cloudy, but afterwards clear again, owing to the volatilization of the reduced antimony. Treated with tin, the glass becomes after cooling gray, even if but very little antimonious acid is present. With strong blowing it becomes clear again.
O	O
OFl: A small quantity is easily dissolved to a clear yellow glass, which on cooling becomes colorless. On a large addition of oxide the glass while hot is yellowish red, becomes yellow on cooling, and when cold is opalescent. RFl: On Ch the glass becomes at first gray and cloudy, the oxide is reduced to metal with effervescence, and the bead becomes clear again. An addition of tin accelerates the reaction.	OFl: Readily dissolved to a limpid yellow glass which on cooling becomes colorless. When a greater quantity of oxide is present the glass may be made enamel-white by flaming, and on a still larger addition it becomes by itself enamel-white on cooling. RFl: On Ch, particularly when tin is added, the glass remains colorless and limpid when hot, but becomes on cooling dark-gray and opaque.
OFl: Soluble in large quantity to a limpid yellowish glass, becoming almost colorless on cooling. When slightly saturated it may be made enamel-white by flaming, and when still more oxide is present it becomes by itself enamel-white on cooling. RFl: Placed on Ch it enters into ebullition; the oxide is reduced; the reduced metal vaporizes immediately and deposits a dark yellow Ct.	OFl: Soluble in large quantity to a limpid glass which while hot is yellowish, but colorless when cold; when saturated it becomes enamel-white on cooling. RFl: On Ch the oxide becomes slowly and imperfectly reduced. The reduced metal deposits a very feeble Ct of dark yellow color. The color is only clearly seen when the mass is cold. An addition of tin facilitates the reduction.

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TABLE II.—CON-

Metallic Oxides in Alphabetical Order.	On Charcoal alone.	With Carbonate of Soda.
5. SESQUIOXIDE OF CERIUM.	Not changed.	Insoluble. The Sd passes into the Ch; the Sesquioxide is reduced to protoxide which remains on the Ch as a light gray powder.
6. SESQUIOXIDE OF CHROMIUM.	Not changed.	OFl: On platinum wire soluble to a dark yellowish brown glass, which on cooling becomes opaque and yellow. RFl; The glass becomes opaque and green on cooling On Ch it cannot be reduced to metal; the Sd passes into the Ch. and the oxide remains behind as a green powder.
7. OXIDE OF COBALT.	OFl: Not changed. RFl: It is reduced to metal, but does not fuse: the mass is attracted by the magnet, and, by friction, assumes metallic lustre.	OFl: On platinum wire a very small quantity is dissolved to a transparent mass of a pale reddish color, which on cooling becomes gray RFl: On Ch reduced to a gray magnetic powder.
8. OXIDE OF COPPER.	OFl: Fuses to a black globule, which becomes reduced where it is in contact with the Ch. RFl: Reduced to metal at a temperature below the melting point of copper When the heat is increased a globule of metallic copper is obtained.	OFl: On platinum wire soluble to a limpid glass of green color; on cooling it becomes opaque and white. RFl: On Ch easily reduced to metal, which when the temperature is sufficiently high fuses to one or more globules.

TINUED.

With Bx on Platinum Wire.	With S Ph on Platinum Wire.
OFl: Soluble to a limpid glass of dark yellow or red color, which changes on cooling to yellow. When highly saturated with oxide the glass becomes on cooling enamel white. RFl: The yellow glass becomes colorless. A highly saturated bead becomes on cooling enamel-white and crystalline.	OFl: As with Bx, but on cooling colorless. RFl: Perfectly colorless, hot and cold. Never becomes opaque on cooling, however large the amount of oxide.
OFl: Dissolves but slowly, but colors intensively. If little of the oxide is present the glass, while hot, is yellow, when cold, yellowish green; with more oxide it is dark red, while hot, becomes yellow on cooling, and when perfectly cold has a fine yellowish green color. RFl: The glass is green, hot and cold. The intensity of the color depends on the amount of oxide present. Tin causes no change.	OFl: Soluble to a limpid glass which, when hot, appears reddish; when cold it has a fine green color. RFl: As in OFl.
OFl: Colors very intensively.—The glass appears pure smalt-blue, hot and cold. An excess of oxide imparts to the bead a deep bluish black color. RFl: As in OFl.	OFl: As with Bx, but for the same quantity of oxide the color is not quite so deep. RFl: As in OFl.
OFl: A small addition of oxide makes the glass appear green while hot, but blue when cold. A large quantity imparts to it a very deep green color, while hot, becoming greenish blue when cold. RFl. A glass containing a certain quantity of oxide becomes colorless, but on cooling becomes opaque and red, (suboxide.) On Ch the copper may be precipitated in the metallic state, the bead becoming in consequence colorless. A glass containing protoxide when treated on Ch with tin, becomes on cooling brownish red and opaque.	OFl: As with Bx, but for the same quantity of oxide the color is not so deep. RFl: A glass containing a large quantity of oxide becomes dark green, which in the moment of solidification changes suddenly to brownish red and opaque. A glass containing but little oxide, when treated on Ch with tin appears colorless, while hot, but becomes brownish red and opaque on cooling.

TABLE II.—CON-

Metallic Oxides in Alphabetical Order.	On Charcoal alone.	With Carbonate of Soda.
9. TEROXIDE OF GOLD.	When heated to ignition it becomes reduced to metal in OFl and RFl. The metal fuses easily to a globule.	Does not dissolve in the Sd, but is easily reduced. in both flames. The metal fuses readily to a globule. The Sd passes into the Ch.
10. OXIDE OF INDIUM.	RFl: Is reduced and forms a yellow Ct, and when strongly heated colors the flame intense blue.	RFl: Is reduced to soft metallic globules, like lead.
11. SESQUIOX-IDE OF IRON.	OFl: Not changed. RFl: Becomes black and magnetic.	OFl: Insoluble. RFl: On Ch it is reduced; the mass. when placed in a mortar, pulverized and repeatedly washed with water to remove the adherent Ch particles, yields a gray metallic powder which is attracted by the magnet.
12. BINOXIDE OF IRIDIUM.	At a red-heat becomes reduced; the reduced metal is infusible.	OFl: Does not dissolve in the Sd, but becomes reduced; the metal cannot be fused to a globule. RFl: As in OFl.
13. OXIDE OF LEAD.	Minium, when heated on platinum foil. blackens; on increasing the temperature it changes into yellow oxide, which finally fuses to a yellow glass. On Ch in OFl and RFl almost instantaneously reduced to metal which, with continued blowing, vapor izes, and covers the Ch with yellow oxide, surrounded by a faint white ring of carbonate. The Ct, when touched with the RFl disappears, imparting to the flame an azure-blue tinge.	OFl: On platinum wire readily dissolved to a limpid glass which, on cooling, becomes yellowish and opaque. RFl: On Ch reduced to metal which, with continued blowing, covers the Ch with oxide.

TINUED.

With Bx on Platinum Wire.	With S Ph on Platinum Wire.
As with Carbonate of Soda.	As with Carbonate of Soda.
Bead colorless, after flaming gray and opaque.	Bead colorless, turns gray when tin is added.
OFl: A small amount of oxide causes the glass to look _yellow while hot, colorless, when cold — When more of the oxide is present the glass, while hot, appears red, and yellow, when cold. A still larger quantity makes the glass dark red, while hot, and dark yellow, when cold. RFl: The glass becomes bottle green. Treated on Ch with tin it becomes, at first, bottle-green, but afterwards pure vitriol-green.	OFl. When at a certain point of saturation the glass, while hot, appears yellowish red, and beco met on cooling at first yellow, then greenish and, finally, colorless. On a very large addition of oxide it appears, while hot, deep red, becoming, on cooling, brownish red, then of a dirty green color, and finally brownish red. RFl: A glass containing but little of the oxide suffers no visible change. When more of the oxide is present it is red, while hot, and, on cooling, becomes at first yellow, then greenish, and finally, reddish. Treated with tin on Ch the glass, on cooling, becomes at first green, and finally colorless.
As with Carbonate of Soda.	As with Carbonate of Soda.
OFl: Easily soluble to a limpid yellow glass which, on cooling, becomes colorless. If much oxide is present, it may be made cloudy by flaming. A still larger addition of oxide causes the bead to become enamel-yellow, on cooling. RFl: The glass diffuses itself over the Ch and becomes cloudy. With continued blowing the oxide is reduced to metal. with effervescence, and the glass becomes clear again.	OFl: As with Bx. But to obtain a glass which appears yellow, while hot, a large addition of the oxide is required. RFl: On Ch the glass becomes grayish and cloudy. This phenomenon is better observed when tin is added; but the glass can never be made quite opaque. If much of the oxide is present, the Ch becomes coated.

TABLE II.—CON-

Metallic Oxides in Alphabetical Order.	On Charcoal alone.	With Carbonate of Soda.
14. SESQUIOX- IDE OF MAN- GANESE.	OFl: Insoluble. When the temperature is sufficiently high both the sesquioxide and the peroxide are converted into a reddish brown powder. RFl: The same effect.	OFl: On platinum wire or foil a very small quantity dissolves to a transparent green mass, which on cooling becomes opaque and bluish green. RFl: On Ch it cannot be reduced to metal; the Sd passes into the Ch and leaves the protoxide behind.
15. PROTOX- IDE OF MER- CURY.	Instantly reduced and volatilized.	Heated in a matrass to redness, it is reduced and vaporized. The vapors condense in the neck of the matrass and form a metallic coating.
16. MOLYBDIC ACID.	OFl: Fuses, becomes brown, vaporizes, and deposits on the Ch a yellow Ct, which nearest to the assay is crystalline. On cooling the Ct becomes white and the crystals colorless. RFl: The greater part of the assay is absorbed by the Ch, and may be reduced to metal at a sufficiently high temperature; the metal is in the shape of a gray powder.	OFl: On platinum wire dissolves with effervescence to a limpid glass which, on cooling, becomes milk white. RFl: Fusion with effervescence. The fused mass is absorbed by the Ch, and part of the acid is reduced to metal which may be obtained as a steel-gray powder.
17. OXIDE OF NICKEL.	OFl: Not changed. RFl: On Ch reduced to metal; the spongy mass cannot be fused to a globule, but assumes metallic lustre by friction; it is attracted by the magnet.	OFl: Insoluble. RFl: Easily reduced to metal in the shape of bright white scales, which are attracted by the magnet.

TINUED.

With Bx on Platinum Wire	With S Ph on Platinum Wire.
OFl: Colors very intensively. The glass, while hot, is violet. on cooling it assumes a reddish tinge When much manganese is added, the glass becomes quite black and opaque; but the color can be seen when the glass, while soft, is flattened with the forceps. RFl: The glass becomes colorless. If the color was very dark, the phenomenon is best observed on Ch with addition of tin.	OFl: A considerable addition of manganese must be made to produce a colored glass; it then appears, while hot, brownish violet, and reddish violet when cold. but never opaque. If the glass contains so small a quantity of manganese that it appears colorless, an addition of nitre will produce the characeristic coloration RFl: Becomes very soon colorless.
O	O
OFl: Dissolved in large quantities to a limpid glass which. while hot. appears yellow, but colorless on cooling. A very large amount of acid causes the glass to appear dark yellow, while hot, and opaline when cold RFl: A highly saturated bead becomes brown and opaque when still more acid is present.	OFl: Easily soluble to a limpid glass; if but little of the acid is present it is yellowish green, while hot, but when cold almost colorless. On Ch the glass becomes very dark, and on cooling assumes a beautiful green color. RFl: The glass assumes a very dark, dirty green color which, on cooling, becomes beautiful bright green. The same on Ch; tin deepens the color a little.
OFl: A small quantity colors the bead violet, while hot; when cold pale reddish brown. More oxide makes the coloration deeper. RFl: The glass becomes gray and cloudy, or even opaque. With continued blowing the minute particles of reduced metal collect together and the glass becomes colorless. This takes more readily placed on Ch, especially when tin is added. The nickel then unites with the tin to a globule.	OFl: Soluble to a reddish glass which, on cooling, becomes yellow. A larger addition causes the glass to appear brownish red, while hot, and reddish yellow when cold. RFl: On Platinum wire not changed. On Ch with tin it becomes, at first, gray and opaque; with continued blowing the nickel becomes reduced, and the glass clear again and colorless.

TABLE II.—CON-

Metallic Oxides in Alphabetical Order.	On Charcoal alone.	With Carbonate of Soda.
18. BINOXIDE OF OSMIUM.	OFl: Converted into osmic acid, which without depositing a Ct. volatilizes with its peculiar pungent odor. RFl: Easily reduced to a dark brown and infusible metallic powder.	Easily reduced to an infusible metallic powder.
19. PROTOXIDE OF PALLADIUM.	Reduced at a red heat: but the metallic particles are infusible.	Insoluble: The Sd passes into the Ch, and leaves the Palladium behind.
20. BINOXIDE OF PLATINUM.	Like Palladium.	Like Palladium.
21. PROTOXIDE OF SILVER.	Easily reduced to metallic silver, which unites to one or more globules.	Instantly reduced. The Sd passes into the Ch, and the metal unites to one or more globules.
22. TELLUROUS ACID.	OFl: Fuses, and is reduced with effervescence· The reduced metal becomes instantly vaporized and covers the Ch with tellurous acid; the Ct usually has a red or dark yellow edge. RFl: As in OFl; the outer flame appears bluish green colored.	Soluble, on platinum-wire. to a limpid and colorless glass, which on cooling becomes white. On Ch reduced and volatilized, depositing a Ct of tellurous acid.
23. OXIDE OF THALLIUM.	Volatizes coloring flame green.	The color of Soda obscures the green color·
24. BINOXIDE OF TIN.	OFl: The protoxide burns, like tinder, to binoxide. The binoxide becomes very luminous and appears white hot, yellowish. but assumes on cooling a dirty white color. RFl: With a powerful and continued flame it may be reduced to metal.	OFl: On platinum wire it forms with Sd, with effervescence, an infusible compound RFl: On Ch reduced to metallic tin.

TINUED.

With Bx on Platinum Wire.	*With S Ph on Platinum Wire.*
o	o
OFl and RFl: Reduced, but not dissolved; the metallic particles cannot be fused to a globule.	As with Bx.
Like Palladium.	Like Palladium.
OFl: In part dissolved, and in part reduced. On cooling the glass becomes opalescent or milk white, according to the amount of oxide present. RFl. The glass at first becomes gray, but afterwards limpid and colorless.	OFl: Imparts to the bead a yellowish color. When much of the oxide is present the glass, when cold, is opalescent and appears yellowish at day-light, reddish at candle-light. RFl: As with Bx.
OFl: Soluble to a limpid and colorless glass which on Ch, becomes gray from reduced metal. RFl: On Ch becomes at first gray, afterwards colorless. The Ch becomes coated with tellurous acid	As with Borax.
Glass. Colorless when saturated, opaque on cooling.	As with Borax.
OFl: A very small quantity dissolves slowly to a limpid and colorless glass, which remains so on cooling. RFl: From a highly saturated glass a part of the oxide may be reduced on Cn.	OFl: As with Borax. RFl: The glass, containing oxide, suffers no change.

TABLE II.—CON-

Metallic Oxides in Alphabetical Order.	On Charcoal alone.	With Carbonate of Soda.
25. TITANIC ACID.	OFl: Assumes, on heating, a yellow color, and becomes white again on cooling. Suffers no other change. RFl: As in OFl.	OFl: On Ch it dissolves with effervescence to a dark yellow glass which on cooling crystallizes. When cold it is grayish white. RFl : As in OFl ; cannot be reduced to metal.
26. TUNGSTIC ACID.	OFl: Not changed ; at a very high temperature converted into oxide, but does not fuse. RFl: Blackens, being converted into oxide, but does not fuse.	OFl : On platinum wire it dissolves to a limpid and deep yellow glass, which on cooling becomes crystalline and opaque, and of white or yellowish color. RFl: With very little Sd on Ch it is reduced to metal ; with more Sd it forms a yellow compound of metallic lustre, which passes into the Ch.
27. SESQUI-OXIDE OF URANIUM.	OFl: Infusible : but assumes a dirty yellowish green color. RFl: Blackens, owing to the formation of protoxide.	OFl . Insoluble. With a certain amount of Sd the mass becomes yellowish brown, and with more passes into the Ch. RFl : As in OFl ; no reduction to metal takes place.
28. VANADIC ACID.	Fusible. Where it is in contact with the Ch it becomes reduced and passes into the Ch. The rest assumes the lustre and color of graphite.	Unites to a fusible mass which is absorbed by the Ch.

TINUED.

With Bx on Platinum Wire.	With S Ph on Platinnm Wire.
OFl: Easily soluble to a limpid glass which, when containing a large quantity, appears yellow, while hot, but becomes colorless on cooling. When containing a very large quantity it is enamel-white, when cold. RFl: When containing but little titanic acid the glass becomes yellow, when more, dark yellow to brown. A saturated glass becomes enamel-blue by flaming.	OFl: Easily dissolved to a limpid glass which, when containing a large quantity, appears yellow, while hot, but becomes colorless on cooling. RFl: Appears yellow, while hot, but, on cooling, reddens and finally assumes a violet color. It iron is present the glass, on cooling, becomes brownish red; with tin on Ch the glass becomes violet, unless the amount of iron be very considerable.
OFl: Like titanic acid. RFl: A glass, containing but little tungstic acid, is not changed When more, it becomes yellow and, on cooling, yellowish brown. On Ch the same reaction is produced with a less saturated bead. Tin deepens the colors.	OFl: Easily dissolved to a limpid and colorless bead, which, when highly saturated, appears yellow, while hot. RFl: With little blowing the glass appears, while hot, of a dirty green color, blue on cooling; with strong blowing it becomes, on cooling, bluish green. On Ch with tin, deep green. If iron is present, the glass, on cooling, becomes brownish red; with tin on Ch the glass becomes blue or, if the amount of iron is considerable, green.
OFl: Behaves like sesquioxide of iron. When highly saturated the glass may be made enamel-yellow by flaming. RFl: Behaves like sesquioxide of iron The green bead, when at a certain point of saturation, may be made black by flaming. On Ch with tin it becomes dark yellow.	OFl: Dissolves to a limpid yellow glass which, on cooling, becomes yellowish-green. RFl: The glass assumes a dirty green color which, on cooling, changes to a fine green. With tin on Ch the color deepens.
OFl: Dissolved to a limpid glass which, when the quantity of vanadic acid is small, appears colorless, when larger, yellow. and which, on cooling, becomes greenish. RFl: The glass, while hot, appears brownish, and assumes a fine green color on cooling.	OFl: Soluble to a limpid glass whiih, if sufficient vanadic acid is present, appears dark yellow, while hot. and becomes light yellow on cooling. RFl: As with Borax.

TABLE II.—CON-

Metallic Oxides in Alphabetical Order.	On Charcoal alone.	With Carbonate of Soda.
29. OXIDE OF ZINC.	OFl : When heated becomes yellow and, on cooling, white again. It fuses not, but becomes very luminous. RFl : is slowly reduced; the reduced metal becomes rapidly re-oxidized and the oxide deposited on another part of the Ch.	OFl : Insoluble. RFl : On Ch it becomes reduced. The metal vaporizes and coats the Ch with oxide. With a powerful flame the characteristic zinc flame is sometimes produced.

TINUED.

With Bx on Platinum Wire.	With S Ph on Platinum Wire.
OFl: Dissolves readily and in large quantity to a limpid glass which appears yellowish while hot; on cooling it is colorless. When much of the oxide is present the glass may be made enamel-white by flaming; and on a still larger addition it becomes enamel white on cooling. RFl. The saturated glass becomes at first gray and cloudy, and finally transparent again. On Ch the oxide becomes reduced, the metal vaporizes and coats the Ch with oxide.	**As with Borax.**

TABLE III.—BEHAVIOR OF THE ALKALINE

BEFORE THE

	On Ch alone and in the Forceps.	With Carbonate of Soda on Ch.
1. BARYTA.	The Hydrate fuses, boils, intumesces, and is finally absorbed by the Ch. The Carbonate fuses readily to a transparent glass, which on cooling becomes enamel-white. In the forceps it colors the outer flame yellowish green.	Fuses with Sd to a homogeneous mass, which is absorbed by the Ch.
2. STRONTIA.	The Hydrate behaves like hydrate of baryta. The Carbonate fuses only at the edges, and swells out in arborescent ramifications which emit a brilliant light, and when heated with the RFl impart to it a reddish tinge; shows after cooling alkaline reaction. In the forceps, colors the outer flame purple.	Caustic Strontia is insoluble. The Carbonate mixed with its own volume of Sd fuses into a limpid glass, which becomes enamel-white on cooling. At a greater heat the mass enters into ebullition, and caustic Strontia is formed, which is absorbed by the Ch.
3. LIME.	Caustic Lime suffers no alteration. The Carbonate loses carbonic acid, becomes whiter and more luminous, and shows after cooling alkaline reaction. In the forceps it colors the outer flame pale red.	Insoluble. The Sd passes into the Ch and leaves the Lime unaltered on its surface.
4. MAGNESIA.	Undergoes no alterations. The Carbonate becomes caustic and luminous.	It behaves like Lime.
5. ALUMINA	Not changed.	Forms an infusible compound, with slight intumescence. The excess of Sd is absorbed by the Ch.

EARTHS AND THE EARTHS PROPER,
BLOWPIPE.

With Bx on Platinum Wire.	*With S Ph on Platinum Wire.*
The Carbonate dissolves with effervescence to a limpid glass, which when in a certain state of saturation may be made opaque by flaming; when still more saturated it becomes opaque on cooling, even without flaming.	As with Borax.
Like Baryta.	Like Baryta.
Readily dissolved to a limpid glass, which becomes opaque by flaming. The Carbonate dissolves with effervescence. —On a large addition of Lime the glass crystallizes on cooling, but does not become enamel-white.	Soluble in large quantities to a limpid glass which, when sufficient Lime is present, becomes opaque by flaming. When saturated, the glass becomes enamel-white on cooling.
It behaves like Lime, but does not crystallize so well.	Readily soluble to a limpid glass, which becomes opaque by flaming. When saturated, it becomes on cooling enamel-white.
Dissolves slowly to a limpid glass, which remains so on cooling, and which cannot be made cloudy by flaming. A large quantity of Alumina makes the glass cloudy; on cooling, it assumes a crystalline surface.	Soluble to a limpid glass, which remains clear under all circumstances. If too much Alumina is added, the undissolved portion becomes translucent.

TABLE III.—CON-

	On Ch alone and in the Forceps.	With Carbonate of Soda on Ch.
6. GLUCINA.	Not changed.	Insoluble.
7. YTTRIA.	Not changed.	Insoluble.
8. ZIRCONIA	Infusible, but omitting a very brilliant light.	Insoluble.

TINUED.

With Bx on Platinum Wire.	With S Ph on Platinnm Wire.
Soluble in large quantities to a limpid glass, which becomes opaque by flaming When Glucina is present in excess it becomes enamel-white on cooling.	As with Borax,
Like Glucina.	Like Glucina.
Like Glucina.	Dissolves more slowly than with Borax.

5

7.—Test with Soda.

The substance to be examined is pulverized, mixed with soda, moistened a little and spread on coal. At first it should be heated gently, but after the moisture is driven off the temperature should be raised as high as possible. It should now be observed, first, whether the assay effervesces, and fuses with the soda; or second, whether it is reduced; or third, whether neither one nor the other occurs, in which case the melted soda sinks gradually into the coal, and the assay remains unchanged.

Silicic, titanic, tungstic and molybdic acids effervesce, and fuse with the soda. Silicic and titanic acids under these circumstances melt to a bead. The former only gives, (when not too much soda is employed), a bead which remains transparent after cooling, while that of the latter becomes, in cooling, opaque and crystalline. Tungstic and molybdic acids are absorbed by the coal as tungstate and molybdate of soda. It should also be noticed here that salts of baryta and strontia form, when fused with soda, compounds which are absorbed by the coal.

All the oxides of the noble metals, as well as the oxides and acids of molybdenum, tungsten, antimony,

arsenic, tellurium, copper, quicksilver, bismuth, tin, lead, zinc, cadmium, nickel, cobalt and iron are reduced on coal with soda, when heated by the reducing flame. Arsenic and quicksilver are instantly volatilized, and sometimes leave behind a scarcely perceptible deposit on the coal. Antimony, tellurium, bismuth, lead, thallium, zinc, cadmium and indium are partially volatilized, and form on the coal distinct incrustations. The fixed metals, when thus reduced, are found either melted or unmelted in the soda, and are best detected by grinding the part of the coal into which the soda has sunk in an agate mortar, and carefully washing off the particles of coal with water. Those metals which are fusible and malleable remain in the mortar as flat pieces and scales, and the infusible and unmalleable as a powder with a metallic luster. Instead of soda, it is better, according to Plattner, to use with those oxides which are reduced with difficulty, oxalate of potassa. Soda is, moreover, employed as a special reagent for detecting manganese, especially when present in very small quantity. When a substance containing manganese is fused on platinum foil in the oxidizing flame with soda, or better with a mixture of soda and saltpeter, a mass is obtained which is colored green, or when cold bluish green, by manganate of soda.

8.—SPECIAL TESTS.

By the methods thus far given for assaying with the blowpipe, it is not always possible to decide with certainty upon all the substances which may appear, but it is often

necessary to undertake for this purpose still further experiments. These experiments, which have for their object the special determination of certain substances, or serve to confirm results previously obtained, are briefly given below.

POTASSA.—The presence of potassa in substances, which besides this contain so much soda or lithia as to prevent its reaction on the blue flame of the blowpipe, (see Test in the Platinum Forceps), can, when the quantity is sufficiently large, be proved by dissolving in a bead of borax, colored brownish by oxide of nickel, a portion of the assay, and observing the color of the bead when cold. A more or less distinct bluish tinge denotes the presence of potassa. Since the reaction depends, of course, upon the quantity of the assay in the bead, it must be gradually increased to the required amount. The bead must be heated on the platinum wire in the oxidating flame.

LITHIA.—Silicates which contain only a small quantity of lithia, as, for instance, many turmalines and scapolites, either do not redden the exterior flame at all or only very slightly. In this case it is necessary to adopt the method proposed by Turner, by which even a small amount of lithia may be detected. The process is as follows: The silicate is pulverized as finely as possible and made into a paste with a mixture of one part of fluor-spar with one and a half parts of bisulphate of potassa and a little water, and fused on the platinum wire in the blue flame, the color of the exterior flame being carefully noticed. According to Merlet, it is often

necessary in order to be positive in regard to the reaction
to use two parts of the mixture with one part of the
assay.   If the silicate contains a small quantity of lithia,
the outer flame will be colored red, though not so brightly
as from lithia alone, the color inclining strongly to the
violet of the potassa.   If the silicate be free from lithia,
only the violet color of the potassa appears.   If it con-
tains soda, it is not always possible to obtain a distinct
reaction from the lithia.   If boracic acid be present in
the silicate, as in turmaline, the outer flame exhibits first
a green tinge denoting the presence of the· acid, but
afterwards a wine or less intense red from the lithia.
Another method of detecting lithia when mixed with soda
is said to be to dip the assay, moistened with hydrochloric
acid, into melted wax and then heat it in the blue flame,
by which, at the first moment, a red color is produced.

BORACIC ACID.—Turner has proposed the following
method of testing for boracic acid in salts and minerals:
The assay is to be pulverized as finely as possible and
made into a paste with water and a flux consisting of
four and a half parts of bisulphate of potassa and one
part of fluor-spar, which is perfectly free from boracic
acid, and fused on the platinum wire in the blue flame.
While the mass is fusing fluo-boracic acid is formed
which is driven off and colors the exterior flame a deep
yellowish green, (siskin-green.)   The green color of the
flame continues, however, only so long as fluo-boracic
acid gas is disengaged.   If, therefore, the quantity of
boracic acid be small, strict attention must be given,

since the color lasts only the few seconds in which the materials of the bead are operating on each other. According to Merlet, it is often necessary, in order to obtain a reliable result, to employ with one part of the assay three or four parts of the flux.

SILICIC ACID.—This may be most easily detected in silicates by heating a small splinter or fragment in a bead of salt of phosphorus. The silicic acid, being nearly insoluble in the salt, is separated from the soluble parts and forms a more or less transparent mass of the form of the assay used, which is called a siliceous skeleton.

SULPHURIC ACID AND SULPHUR.—In sulphates, sulphides, and indeed in all substances containing sulphur, the smallest trace even of this element may be detected by mixing the assay with two or three parts of soda, or according to Plattner, with the same quantity of oxalate of potassa, (which is perfectly free from sulphuric acid), and heating the mixture in the reducing flame on charcoal. The melted mass, when cold, is laid, with that part of the coal into which it has sunk, on a piece of bright silver and moistened with water. If sulphur be present and has accordingly formed sulphide of sodium, there appears sooner or later a black or brown stain of sulphide on the silver. It must, however, be observed that selenium gives the same reaction. Von Kobell gives the following directions for determining whether the sulphur in a mineral belongs to a sulphide or to a sulphate. The finely pulverized assay is fused with hydrate of potassa in a platinum spoon before the blowpipe. The

platinum spoon with its contents is then placed with a bright piece of silver in a small porcelain dish of water. If the substance contains a sulphide, the silver is blackened, but if a sulphate, it remains perfectly bright. In the latter case, the sulphur must first be proved present on coal with soda, and, of course, that portion which is melted in the platinum spoon must not have been exposed to any reducing influence.

NITRIC ACID.—Nitrates heated in a matrass give off first oxygen, and then nitrous acid, which may be recognized from its yellow color as well as peculiar odor. Nitrates of potassa and soda deflagrate when heated on charcoal. A small quantity of nitric acid may be detected in a substance by heating a portion of it in a matrass with a little more than an equal weight of bisulphate of potassa. The color of the nitrous acid gas may be most distinctly seen by looking directly into the open end of the matrass and thus through as thick a stratum as possible of the mixed gases.

FLUORINE.—When hydrofluoric acid in small quantity occurs in minerals with any of the heavier metals and a small quantity of water, it is only necessary, according to Berzelius, to heat the assay in a glass tube closed at one end, and into the open end to introduce a strip of moistened Brazil-wood paper. Hydrofluosilicic acid is driven off by the heat and deposits not far from the assay a ring of silica, and the Brazil-wood paper is turned straw-yellow by the action of the resulting hydrofluoric

acid. This reaction may be obtained, when as in some micas the hydrofluoric acid amounts to no more than three-fourths of one per cent. If the substance, whether a mineral or a slag, exhibits no reaction of hydrofluoric acid either on the glass or the Brazil-wood paper, it should, according to Berzelius, be treated as follows : The pulverized assay is mixed with salt of phosphorus, which has been previously melted on coal and then pulverized, and heated at one end of an open glass tube, so that the current of hot air shall pass over it and through the tube. Minerals containing no silicic acid, treated in this way, give off water and hydrofluoric acid, which passing through the tube may be recognized as well by its suffocating odor as by its power of attacking the glass which is rendered dim throughout its entire length, especially in those places where moisture is deposited. If a strip of moistened Brazil-wood paper be held before the current of air at the upper end of the tube, it is turned yellow by the hydrofluoric acid. If the substance contain silicic acid, fluoride of silicon is given off, which is, however, decomposed by the water formed by the combustion of the alcohol or oil, and the silica remains dissolved in it. When the water condensed in the tube is evaporated, the silica remains behind and may be distinctly seen. If the tube be washed with water and dried, the etching effect of the hydrofluoric acid may be observed on the glass. A strip of moistened Brazil-wood paper introduced into the tube at the beginning of the experiment is colored yellow. Since in such experiments it is necessary to fuse the substances, it often

happens in using glass tubes that the glass becomes so
soft that the blowing must be suspended. To avoid this
difficulty, Smithson fastens to one end of the glass tube
by means of a metallic wire a piece of platinum foil so
that it forms a half-tube or canal outside the glass tube.
The assay is now laid on the foil and the blast so directed
as to drive the products of the ignition into the tube.
The use of the wire may be dispensed with by cutting
down the sides of a strip of foil for two thirds of its
length and then rolling it together and introducing the
other third into the glass tube. This has the advantage
of preventing the assay, during or after the fusion, from
coming in contact with the glass. Plattner always
obtains in this way satisfactory results with both minerals
and slags, whether the fluorine constitute an essential
part of the substance or be present only as an accidental
ingredient. According to Merlet, substances which do
not contain too small a quantity of fluorine may be tested
by heating them, after being finely pulverized, in a mat
rass with equal parts, (according to Berzelius with four
parts), of fused bisulphate of potassa, till sulphuric acid
begins to be set free. The heat, which may be that of a
spirit lamp or of the blowpipe flame, should not be ap-
plied to the bottom of the matrass but to the side, since
otherwise the mass is apt to rise in the tube. The empty
part of the matrass becomes thus lined with silica which
is deposited by the decomposition of fluosilicic acid gas.
The tube may then be cut off just above the melted mass,
rinsed with water and dried with bibulous paper. If the
quantity of fluorine be considerable, the walls of the

tube are etched throughout; if the quantity be small, they show only here and there a dim spot. This method is, however, not so good for detecting minute quantities of hydrofluoric acid as that with salt of phosphorus in the open glass tube.

CHLORINE, (CHLORIDES AND CHLORATES).—According to Berzelius, the presence of chlorine in its compounds is detected as follows : A bead of salt of phosphorus is heated in the oxidizing flame and a sufficient quantity of oxide of copper added gradually to render it nearly opaque. A portion of the substance to be tested is attached to the still fluid bead, which is then heated in the reducing flame. If chlorine be present, the bead is surrounded by a flame of a beautiful blue inclining to purple, which continues as long as chlorine remains. A fresh portion of the assay renews the reaction. No other acid found in minerals, except bromine, produces a similar flame. A second method, also given by Berzelius, for detecting chlorine in the metallic chlorides, which are soluble in water, is to lay upon a bright piece of silver a little sulphate of iron or copper, moisten with a few drops of water, and then to place in it a portion of the chloride. The silver becomes after a while stained of a deep bronze color. According to Merlet, the insoluble chlorides may be tested for chlorine in the same way by first melting them with soda on the platinum wire so to form soluble chloride of sodium.

BROMINE.—According to Berzelius, the metallic

bromides give with salt of phosphorus and oxide of copper the same reaction as the chlorides ; but the blue color imparted to the flame by bromine inclines not to purple, but to green, especially on the edges. To distinguish with certainty the bromides and bromates from the chlorides and chlorates, it is necessary, according to Berzelius, to fuse them in a matrass with bisulphate of potassa. When thus treated, the former give off bromine and sulphurous acid, (and the latter, chlorine and sulphurous acid), and fill the matrass with reddish-yellow vapors which may be distinctly recognized by their offensive odor resembling that of chlorine, notwithstanding the presence of sulphurous acid. If the quantity of bromine in the assay is small and the foregoing method be employed, it is important when the color cannot be observed from the side of the matrass, to look directly into it through the thickest possible stratum of gas. If the assay contain chlorine, this is also given off under these circumstances, but the yellow color is in small quantities scarcely perceptible. When iodine is also present, a mixture of yellow vapors of bromine and violet vapors of iodine is obtained.

IODINE, (METALLIC IODIDES AND IODATES).—Metallic iodides, according to Berzelius, when tested in the bead of salt of phosphorus and oxide of copper, communicate to the exterior flame of the blowpipe a beautiful deep green color. When fused with bisulphate of potassa in the matrass, they give off sulphurous acid and iodine which is partly sublimed and partly fills the tube with

violet vapors. To discover a small amount of iodine in mineral water which has been freed from the greater part of its chloride of sodium by evaporation, a solution of starch in boiling water and water saturated with chlorine is generally employed, an insoluble compound being thus formed, which possesses a remarkably fine blue color. Heine uses, with better results, instead of chlorine water nitric acid, and tests as follows: The neutral fluid to be examined for iodine is mixed with a small quantity of a solution of starch in hot water, and stirred with a glass rod while a few drops of nitric acid are added. If iodine be present even in very small quantity, there appears directly an intense blue color.

MAGNESIA, COLUMBIC ACID, ALUMINA, OXIDES OF ZINC, TIN AND ANTIMONY, TITANIC ACID, NIOBIC ACID, ZIRCONIA.—All these substances, when moistened with a solution of nitrate of cobalt and ignited, assume certain characteristic colors. The pulverized assay should be made into a stiff paste with water, spread on coal and gently heated. After the water is evaporated a drop of the solution of cobalt is to be added, which is absorbed by the dry porous mass. This should then be gently heated to decompose the nitrate of cobalt, and afterwards strongly ignited by the oxidating flame. When the assay is perfectly cold, these substances exhibit the following colors:

Magnesia, rose red, (not intense) ; Columbic Acid, similar to magnesia.

Alumina, beautiful blue, (smalt blue).

Oxide of Zinc, beautiful yellowish-green, (siskin green); Oxide of Tin, bluish-green; Oxide of Antimony, dirty green; Titanic Acid, yellowish-green, (less beautiful than oxide of zinc); Niobic Acid, dirty green. Zirconia, dirty violet.

The purity of the substances is an important requisite to the proper production of these colors. Impurities from other oxides give rise to more or less indistinct, dirty colors; the presence of the alkalies and of silicic acid causes, (by their melting with the oxide of cobalt,) a blue color.

OXIDE OF MANGANESE.—Exceedingly minute quantities of the oxide of manganese—even less than one-tenth of one per cent.—may be detected by fusing the finely pulverized assay in the oxidating flame on platinum foil with two parts of soda and one part of saltpeter. The fused mass is more or less intensely colored by the manganate of soda; when hot, it appears green, when cold, bluish-green, (turquois-color).

TELLURIUM.—A test for tellurium, proposed by Berzelius, is to grind the assay with soda and coal, and heat the mass to fusion in a matrass, and drop upon it when cold a small quantity of recently boiled water. This after a little time is colored more or less intensely purplish red from the dissolved telluret of sodium.

ARSENIC.—A small quantity of arsenic in a metallic compound, as for instance, in nickel, cobalt, or any alloy containing arsenic, can often be detected with sufficient